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Focus on bioenergy industry development and energy security in China

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ABSTRACT

This paper focuses on the relationship between bioenergy industry and energy security. The situation of fuel ethanol, biodiesel, biogas and biomass power industry of China in recent years has been introduced comprehensively. With a quick look at the existing bioenergy industrial development policies, combined with China′s energy security situation, we drew the following conclusions: (1) the bioenergy industry is an effective way to achieve China′s energy security; (2) as for energy substitution from cost aspect, China has already had the ability to make bioenergy substitute for fossil fuels; (3) from technical aspect, however, China′s bioenergy technologies are not mature, this means that in a very long period of time, biomass and fossil energy will jointly develop in a *mutually beneficial* way.

Contents

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1. Introduction

1.1. Background

In recent years, China has made significant achievements in using of bioenergy. The production capacity of fuel ethanol had reached 2.1 million tons in 2012, while it is estimated that production capacity in 2013 would reach 2.3 million tons [15]; China′s production capacity of biodiesel had achieved more than 2.6 million tons in 2012, and will be 3.1 million tons in 2013 [18]; the production capacity of biogas in China in 2012 was over 17 billion cubic meters, which makes China the first place in terms of development potential [17]; up to 2012, China′s total installed capacity of Straw direct-fired power generation was 5819 MW, accounting for 60% of all biomass power generations [18]. It should be believed that bioenergy industry has preliminary formed in China [6].

International Energy Agency (IEA) data shows that in 2010 China has surpassed the U.S. as the world′s largest energy consumer, and has become the world′s largest CO_2 emitter. Estimated by National Bureau of statistics of China, the energy consumption of 2012 reached a total of 3.62 billion ton of coal equivalent (Mtce), with 3.9% more than that of 2011. Among them, the coal consumption was with an increase of 2.5%; crude oil consumption was with an increase of 6.1%; natural gas consumption was with an increase of 10.2%. Meanwhile, in 2012 China′s emissions of GHG accounted for 30% of the world′s total. So the development of bioenergy industry needs to be improved right now.

1.2. Issues

China′s bioenergy industry is in the initial stage of development, without either the scientific market mechanisms to guide or a sound policy framework to support. At the same time, China faces the dual task of energy security and food security [20]. On the one hand, feedstocks for ethanol and biodiesel production make the national food security theoretically more serious [11]. On the other hand, with economic development, China′s energy consumption keeps growing. Oil consumption of China relies heavily on imports. High prices of international oil make China′s energy security faces realistically serious challenges [29]. Uncertainties that bioenergy industry can affect China′s energy security negatively still exist. It is hoped that the question will be resolved in our paper.

2. Current situation of China′s development of bioenergy industry

2.1. Fuel ethanol industry

China′s development of fuel ethanol industry has gone through three major phases: the initial pilot phase (from mid 1990s to 2000), steadily developing phase (2000–2005) and non-food fuel ethanol developing phase (from 2005 to the present). Initially, China′s fuel ethanol production was used to digest the stale corn, wheat and other grains, so fuel ethanol products led agriculture a way to a huge market [32].

China′s current fuel ethanol market structure was formed in 2004. In 2005, China produced nearly 1 million tons of fuel ethanol, ranked after Brazil and the United states. Table 1 shows China′s fuel ethanol consumptions in regional energy market.

With the gradual depletion of stale rice and the obvious increase of corn prices, the development of bio-ethanol might threaten the national food security [2]. In December 2006, the National Development and Reform Commission (NDRC) issued an urgent notice on fuel ethanol project management required using non-food crops as raw materials to realize diversification and encourage the development of non-food crops as raw materials in the progress of fuel ethanol. In June 2007, the State Council of the People′s Republic of China held a conference on renewable energy which made final decisions that the bio-ethanol projects making use of corn and other edible grain must be officially stopped, the future development should adhere to the principle of “No occupation of cultivated land, No waste of consuming food, and No damage of the ecological environment”. Since then, the beginning of the exploration and development of China′s non-food fuel ethanol has been on the go [10].

After years of development, China′s fuel ethanol already has a certain amount of production capacity. From 2002 to 2012, China′s fuel ethanol production grew rapidly [4]. However, with the adjustments of national policies, the capacity slowed down after 2006. Table 2 shows the changes in China′s fuel ethanol production.

Currently, the main raw material for domestic fuel ethanol is corn, accounting for 80%. Table 3 shows the costs of three of them used to produce fuel ethanol.

2.2. Biodiesel industry

Although for biodiesel, China started to research and develop relatively late, some achievements have reached the international advanced level with a rapid pace of development. The achievements involved the distribution, selection, cultivation, processing technology

Table 1
Area analysis of China’s fuel ethanol production and supply.
Source: China Agricultural Development Report 2010.

Suppliers province	Manufacturer	Raw material	Buyers province
Heilongjiang	China Resources Alcohol Co., Ltd.	Corn	Heilongjiang
Jilin	Fuel Ethanol Co., Ltd.	Corn	Liaoning
Anhui	BBCA Biochemical Co., Ltd.	Corn	Anhui, Shandong, Jiangsu, Hebei
Henan	Tian Guan Fuel Ethanol Co., Ltd.	Wheat	Henan, Hubei, Hebei
Guangxi	COFCO Biomass Energy Co., Ltd.	Cassava	Guangxi

Table 2
China's fuel ethanol production over the years.
Source: authors.

Year	Annual production (10,000 t)	Growth rate
2002 and before	No statistics	Na (%)
2003	< 20	
2004	30	1400
2005	92	206
2006	130	41
2007	140	8
2008	158	13
2009	172	9
2010	194	13
2011	204	5
2012	210	3
2013E	230	10

Table 3
China's conversion of the main raw material cost 2012.
source: authors.

Material	Raw materials—ethanol conversion coefficient	Cost of raw materials
Corn	3.2	361 $/ton
Cassava	2.9 (Dry), 7.8 (fresh)	345–525 $/ton
Sweet sorghum	15	574 $/ton

Table 4
Biodiesel industry production capacity and production in China.
Source: authors.

	Production capacity (million ton)	Production (million ton)
2006	1.55	0.24
2007	2.75	0.31
2008	2.95	0.47
2009	2.35	0.52
2010	2.05	0.50
2011	2.30	0.57
2012	2.60	0.62
2013E	3.10	0.69
2014E	3.50	0.71
2015E	4.00	0.75

and equipment of oil plants. Recently, China's biodiesel production projects were mainly in the private enterprises, this would undoubtedly help China to further research and development of biodiesel.

Meeting the global demand for raw materials will be a huge challenge to biodiesel industry. China's *Jatropha curcas*, pistache and other oil plants can meet the demands of 5 million tons per year biodiesel production for raw materials. To solve the problem of raw materials, some foreign enterprises choose to build biodiesel factories in China while sell their products abroad [7].

China's biodiesel production is still small currently. Data of 2012, released by NDRC, was 0.5 million tons with production capacity of 2.6 million tons (Table 4). For such data did not take a number of small businesses into account, the actual production is estimated to be more. Biodiesel industry has been promoted in the support of national policies which planned the annual production of 12 million tons in 2020 [33].

By now, it is so difficult to evaluate specific biodiesel production capacity that it can only be roughly estimated by built and under-construction biodiesel projects. Data from NDRC shows that in 2012 biodiesel manufacturers – completed and to be built – could achieve an annual production capacity of 0.62 million tons. Table 5 shows the number of relative factories up to 2008 [11].

It is with Chinese characteristics and advantages that biochemical refinery takes woody plants as raw materials to produce oil [33]. It indicates that the woody plants oil as biodiesel's raw materials is rather competitive. Recently, wasted edible oil, in China, seems to be a new way to solve such issue. Raw Materials-Biodiesel Conversion Coefficient describes by how many units of raw materials to produce one unit of biodiesel.

During its golden period of development, the number of domestic enterprises involved once reached more than 300. But as of now, the statistics shrank rapidly. By the end of 2011, China has a certain biodiesel production capacity of more than 50 enterprises. Among them, Chinese private enterprises accounted for more than 95% in terms of the biodiesel production capacity and actual production. At present, Chinese private enterprises also failed to enter the biodiesel sales network of three major oil companies. The biodiesel from Chinese private enterprises going to stations was less than 10%. At present, the biodiesel is sold primarily as chemical products or fuel oil into the consumer market [7,8]. Those hurt the investment enthusiasm of investors greatly.

2.3. Biogas industry

China's gas industry which went through the experience of *two declines and three ascents* began in the 1970s. Now it's in its third peak period of development. 2012, the biogas production was about 17 billion cubic meters in China, which was 15.78% of natural gas production with 107.7 billion cubic meters.

2013, The World Bioenergy Association estimated that in China, the total biogas resources are about 274 billion cubic meters, accounting for 27.40% of the world's total resources with one trillion cubic meters. Among them, the agricultural resources are 154 billion cubic meters, accounting for 24.44% of the world's total resources with 630 billion cubic meters, organic waste resources are about 120 billion cubic meters, accounting for 32.43% of world's total resources with 370 billion cubic meters [31]. Up to 2011, China has got 40 million gas customers, produced biogas about 14 billion cubic meters [5]. Fig. 1, data from the Asian Development Bank, shows the comparison of China's areas of

Table 5
The number of biodiesel enterprises up to 2008.
Source: China's New Energy and Renewable Energy Yearbook 2010.

Statistical	Quantity of biodiesel enterprises
Capacity of 10,000 t and below	26
Capacity between 10,000 and 50,000 t	13
Capacity between 50,000 and 100,000 t	7
Capacity of 100,000 t and even more	6

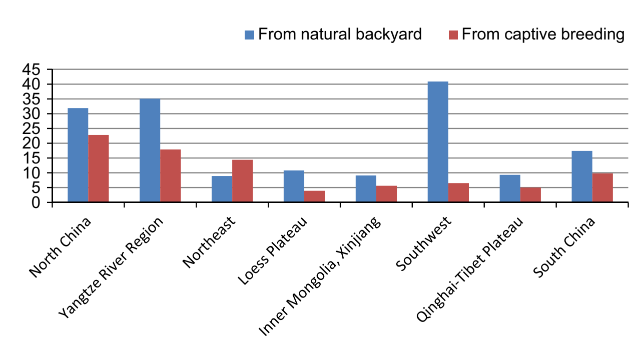

Fig. 1. Regional comparison of China's manure resources for biogas production 2011 (billion m^3).

manure for producing biogas in 2011. The X-axis represents the different areas of China.

China's biogas technology ranks in the international advanced level [2], however, the medium-sized biogas projects started late. Compared with developed countries, there is a large gap in the aspect of broad types of raw materials, methane fermentation technology for different materials, research and development of microbial probiotics, equipment and technology for large-scale biogas facilities, development of methane fermentation products, the comprehensive utilization of solid and liquid residues and so on. All of these are the further strengthening of independent innovation.

The national capital investment continues to increase in recent years. In the 1980s, the government arranged a special fund to support rural areas, including rural energy utilization, biogas construction and development [3]. However, only a few hundred million dollars had been arranged for investment each year. Since 2000, the MAPRC organized the nationwide construction in the name of Biogas Technology for Poverty Demonstration Project which promoted the various types of promotion and application of biogas as a link ecological mode of energy engineering and technology [35]. To rural small-scale public infrastructure projects and rural infrastructure projects, especially "Rural Biogas Construction Bond Projects" in 2003, the government invested heavily to support each of the special projects. Fig. 2 shows investment to the construction of biogas from the government in recent years.

At the same time, various types of biogas projects are being built rapidly, the total soared from 1042 in 2000 to 68,590 in 2012. Only in 2009, more than 17,000 new gas projects came out with annual growth of 42.6%, total volume of 7.1496 million cubic meters completed with annual production capacity of 917 million cubic meters [34].

2.4. Biomass power industry

Along with the "Renewable Energy Law" and subsidies policy of renewable energy, especially the mandatory access system and price subsidies policy, network obstacle of biomass power industry is cleared up [1]. Therefore, China's investment to biomass power generation increases year by year, and various power generation projects of agriculture, forestry and waste start to be under construction.

As of the end of 2012, projects of the provinces (autonomous regions and municipalities) through information management platform declared 591 biomass projects with a total grant additional tariff. Among them, the number of power generation projects was 359, grid-connecting engineerings was 226, public-independent systems was 6. In 2012, the number of official biomass projects was 418 according to the National Energy Bureau. Among them, the power generation projects was 253, grid-connecting engineering was 158. The top three provinces of Shandong, Jiangsu, Province and Henan, respectively, reported 84, 61 and 39 biomass projects.

China's biomass power generation industry has shown a full acceleration of development [16]. In 2012, the construction of biomass power generation industry achieved outstanding results. Based on preliminary estimates, by the end of 2013, China's biomass power installed capacity will be expected to reach 8.50–9.00 GW. Data show that in 2012 the government approved some new capacity of 1156 MW. By the end of 2012, the government authorized a capacity of 8781 MW, in which grid-connecting capacity was 5819 MW and under-construction capacity was 2962 MW. The industry development maintains a rapid growth rate (Fig. 3).

China's biomass power generation technology mainly is straw direct-fired power generation and waste incineration power generation [14]. Up to 2012, China's total installed capacity of straw direct-fired power generation was 326.2 GW, accounting for 55% of all biomass power generation; the total installed capacity of waste incineration power generation was 242.7 GW, accounting for 42%; other techniques, such as gasification power generation, gas generation and power generation fuel mix, shared a small proportion of less than 5%. According to the plan by National Energy Commission (NEC), China's biomass power generation installed capacity would reach 13 GW by 2015. Fig. 4 shows the current structure of China's biomass power industry.

In addition, analysis from the Asian Development Bank predicted that from 2010 to 2020, China's crop residues used for power generation would reach 100 million tons and would be sufficient to meet burning demands to 350 power plants of the installed capacity of 25 GW [30]. And compared to coal power plants with the same scale, 25 GW biomass power plants could reduce CO_2 emissions of 100,000 t per year. What's more, the burning ash of biomass resources could also be used to produce high-quality potash fertilizer.

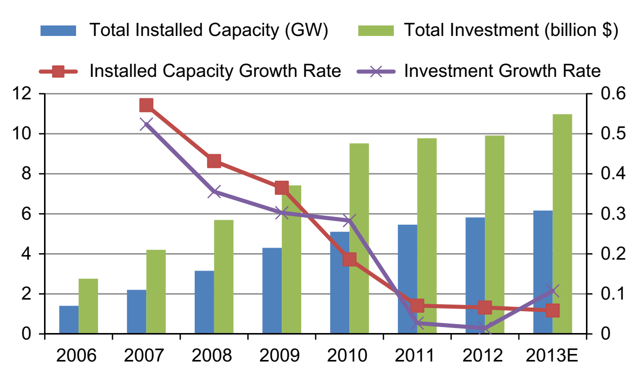

Fig. 3. Scale changing trends of China biomass power generation industry 2006–2012.

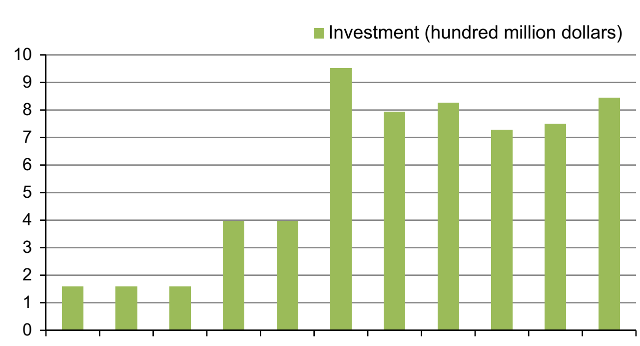

Fig. 2. Chinese government fundings for the construction of biogas 2003–2012.

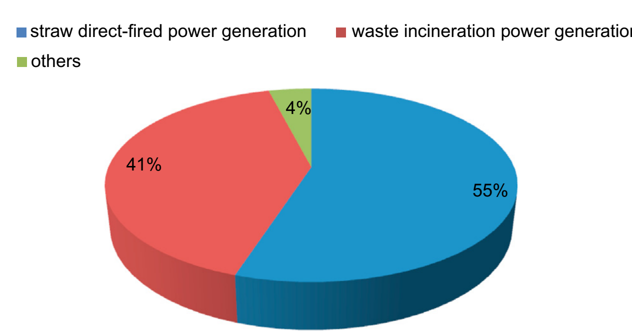

Fig. 4. Biomass power structure of China 2012.

3. Current situation of China's energy security

3.1. Current situation of supply–demand for energy

Data from National Bureau of Statistics shows that, in 2012, China's energy consumption increased by 4.20% over the last year. China's energy consumption of 2012 reached a total of 3620 Mtce. The structure of energy consumption is illustrated in Fig. 5 in 2012. Among them, the coal consumption decreased by 2.0%, crude oil consumption increased by 0.3%, natural gas consumption increased by 0.5%, non-fossil energy increased by 1.1%. Fig. 6 shows the total China's energy production and consumption changes.

With China's sustained economic development, energy supply and demand gap becomes increasingly larger and larger [9]. To make up the energy gap in the domestic market, the only way, now and before, is to rely on imports. In 2012, China's coal imports each month was over 0.29 billion tons, while the exports was 9.28 million tons; total imports of crude oil was 0.27 billion tons, crude oil exports and related products was 2.43 million tons. China's sustained economic growth results in demand for energy actually more year by year which leads to China's energy gap expanding. Figs. 7 and 8 show the changes in response to the situation of China's energy supply–demand gap.

3.2. Current situation of energy prices

In 2012, although China's domestic coal supply and demand was roughly in balance, there were several fluctuations of the market price of coal, regional and periodic [13]. From 2009 to 2011, the price rose slightly in the full year, but it decreased from 2011 to 2012. Fig. 9 shows the degree of China's coal price changes during 2005–2012. In 2012, the main business costs of large coal enterprises in China was with an increase of 25.26%, which made their profit dropped 23.35%. The year of 2013 is the first year of merging coal prices. According to the State Council had issued "Notice on deepening the reform of the electricity market". From 1st January 2013 onwards, the government cancelled the key contracts for coal, and implemented the merging price of coal. In first half year of 2013, there were still a lot of coal in storage for the downstream port and power plants, so thermal coal price hardly rose [19].

The pace of China's oil price increasing has been with the international [1]. In 2011, China's crude oil CIF was 806.08 $/ton, FOB was 806.98 $/ton. Non-tax price of oil is ranked in the middle level of the world. In September 2013, the Ministry of Finance had proposed resource tax reform program. The tax rate of the crude was set at 10%, but would begin implementing with 5%. In recent years, China's refined oil price increases by a big margin. Between 2009 and 2010, gasoline and diesel prices which had been

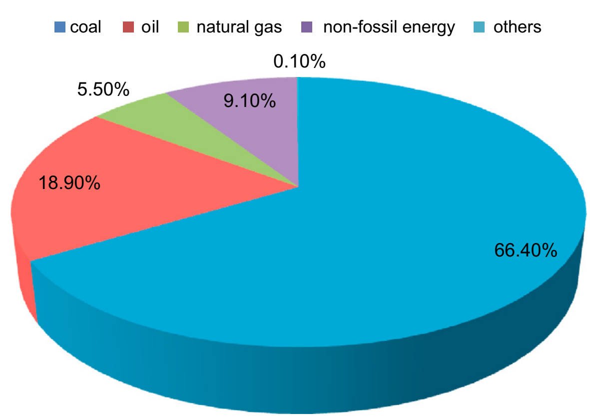

Fig. 5. Structure of energy consumption of China's energy consumption in 2012.

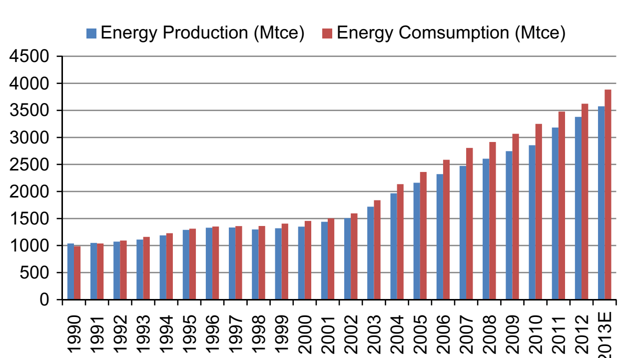

Fig. 6. Changes in the total China's energy production and consumption.

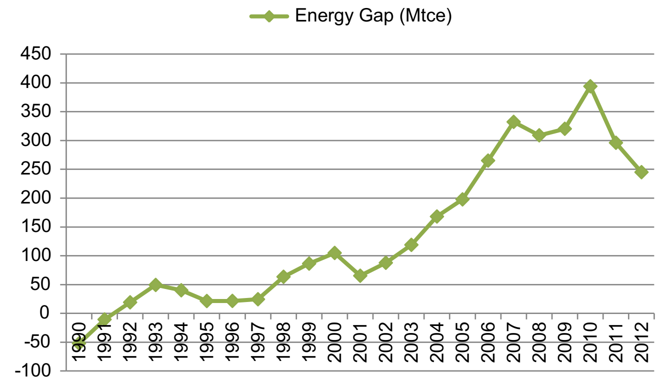

Fig. 7. Changes in response to the situation of China's energy supply–demand gap.

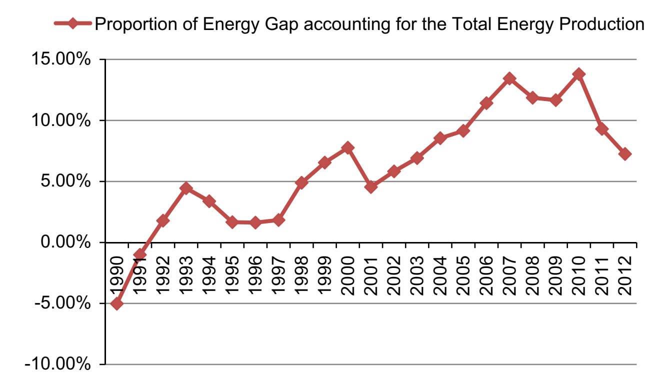

Fig. 8. Changes in the proportion of China's energy gap accounting for total energy production.

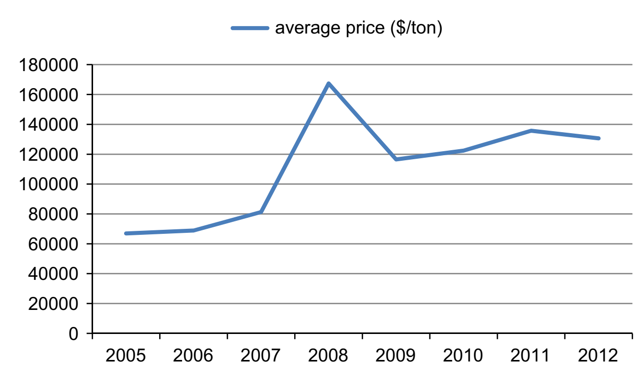

Fig. 9. Changes in the China's coal prices.

adjusted 12 times increased by 38.5% and 40.4%, gradually closer to the international oil price (Table 6).

China's industrial and residential natural gas prices which lie in a lower position of price level from global are growing relatively slow. In 2009, the mean price of China's imported liquefied natural gas was $4.4 per Mega British thermal unit (MBtu), which was in the middle level of the international and with a decline of 19% year-on-year. Fig. 10 shows China's industrial and residential natural gas price changes in recently years [12].

3.3. China's energy and environment dilemma

Because of natural resource endowment, the structural contradiction exists between supply and demand [28]. Data from Ministry of Land and Resources of the People's Republic of China (MLRPRC) shows that ratios of reserves to production of China's coal, oil and natural gas respectively are 58%, 7% and 6% of international average which is calculated for the world as a whole. According to the current proven reserves and scientific exploitation, China's coal, oil, natural gas can be taken for only 82 years, 14 years and 29 years respectively, far away from the international average of 229 years, 44 years and 60 years.

China is in the accelerating period of industrialization and urbanization, in which energy supply still cannot keep up with expanding energy demand [4]. Meanwhile, China's energy resources are very unevenly distributed. Large-scale distribution and long-distanced transport lead to poor transport capacity and expensive costs which, in turn, affect the energy industry development [27,31].

It is the irrational energy consumption structure that leads to ecological carrying pressure. China's energy structure in general is known as "coal in rich, oil in short, gas in poor". Of primary energy consumption, the proportion of coal is over 70%. China's energy structure is still dominated by coal consumption, and according to the information from NDRC, this structure will not change much in short term [28]. Large-scaled using fossil energy results in an increasingly serious problem of environmental pollution. Only air pollution, for example, proves that China's SO_2 and CO_2 emissions ranking first in the world, which makes smoke–dust and CO_2 emissions 70%, SO_2 emissions 90%, nitrogen oxides emissions 67% from coal-fired. China's responsibility of GHG emissions has attracted a worldwide attention of the international. That means the emission reduction obligations under international pressure appear further increased.

The international environment is so complex that it is difficult to use foreign resources for China. According to the information from the Ministry of Industry and Information Technology of the People's Republic of China (MIITPRC), 2012 China's degree of dependence on foreign crude oil was 58.7%, foreign natural gas was 28.9%. China's oil and natural gas are relatively short of resources, so it is wise to expand further international energy cooperation to guarantee the security of production and supply. Because of the fragile balance between the global energy supply and demand, fluctuations of oil market and the oscillations of international oil price, however, international energy cooperation can be affected by various non-economic factors. Under the constraint of lack of global resources, transportation capacity, political issues and international security, using foreign energy resources turns to be more difficult for China [27].

Table 7 shows some related economic Indicators to energy security, which proves the dilemma of energy and environment.

4. Hot issues and policy situation

4.1. Effects of substitution among energy sources

4.1.1. Cost substitution

To promote biomass energy as a substitution to traditional fossil fuel, data [1–5] of China for the duration of 1987–2009, making use of Allen Elasticity of Substitution (AES) [13] and Morishima Elasticity of Substitution (MES) [23], is selected for the empirical analysis. The results shows that: China's demand for biomass will increase with the decrease of price elasticity, while traditional fossil fuel prices and demands varying to the same direction shows that consumption reduction cannot rely on the price control. The reducing in biomass prices will lead to demand for traditional fossil fuel decrease. Then educes: China's fossil fuels of oil and coal, present a certain feature of "*Giffen goods*" or "*inferior goods*", while bioenergy, as one of renewable energy, is expressed as "normal Goods" characteristics; bioenergy is an effective substitution for traditional fossil fuel energy products.

Table 8 shows the result of Own-price elasticity of biomass energy, oil and coal (OPE (BB), OPE (OO), OPE (CC)) and absolute Cross-prices elasticity (CPE), in which CPE is equal to Allen partial elasticity of substitution. Table 9 shows the price elasticity of demand and Relative Cross-prices elasticity (MES). Fig. 11 shows the changes in the price elasticity of demand. Fig. 12 shows the price changes of oil and coal affecting the demand for biomass in AES way (CPE(BO), CPE(BC)); Fig. 13 shows the price changes of biomass affecting the demand for oil and coal the same way (CPE (OB), CPE(CB)). Figs. 14 and 15, in MES way, show the price changes of oil and coal affecting the demand for biomass (MES(BO), MES (BO)) as well as the price changes of biomass affecting the demand for oil and coal (MES(OB), MES(CB)).

4.1.2. Technology substitution

Based on Lotka–Volterra Competition model (LVC) [25] and Parameter Gray Estimation method [14], data [2] of China for duration of 1994–2010 years is selected for the empirical analysis

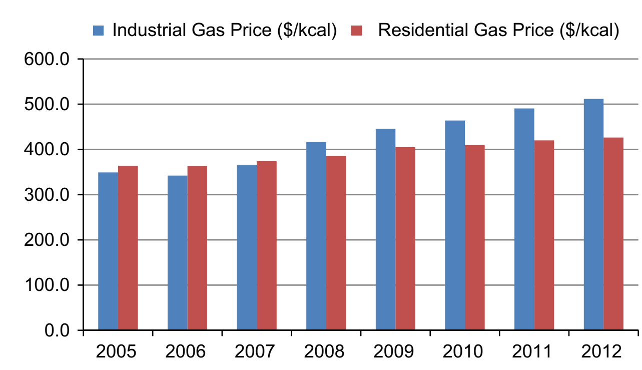

Fig. 10. Changes in China's gas price and its index 2005–2012.

Table 6
2005–2012 China's oil factory price ($/ton).
Source: authors.

	2005	2006	2007	2008	2009	2010	2011	2012	Average annual growth rate (%)
Gasoline	677.7	797.5	832.3	981.2	1021.7	1154.8	1231.1	1310.3	10.02
Diesel fuel	590.8	669.7	763.6	912.7	904.7	1037.3	1121.8	1201.4	10.85

Table 7
China's related indicators of energy security 1995–2012.
Source: authors.

	Elasticity of energy consumption	Reduction rate of energy consumption /per GDP (%)	SO_2 emission reduction rate (%)	Dust emission reduction rate (%)	Proportion of primary energy (%)	Primary energy supply–demand ratio (%)	Self-sufficiency rate of primary energy (%)
1995	0.63	15.27	4.44	−4.53	93.90	98.75	95.84
1996	0.31	11.97	−1.40	11.50	94.01	96.75	95.08
1997	0.05	9.39	−1.15	2.68	93.60	96.78	92.79
1998	0.03	6.24	−14.38	−14.30	93.52	97.09	93.59
1999	0.42	2.85	12.60	20.34	94.10	89.02	92.69
2000	0.42	6.42	−6.92	−0.52	93.58	97.99	90.15
2001	0.40	6.49	2.42	8.15	92.50	92.88	90.02
2002	0.66	3.41	1.10	5.42	92.70	97.37	89.36
2003	1.53	−2.13	−10.74	−3.56	93.51	98.37	88.54
2004	1.60	1.33	−4.28	−4.48	93.28	100.06	86.91
2005	0.93	4.42	−11.55	−8.04	93.22	99.35	88.00
2006	0.76	6.29	−1.52	7.99	93.34	99.12	87.34
2007	0.59	11.75	4.89	9.36	93.18	98.32	86.86
2008	0.41	12.06	6.33	8.57	92.34	98.48	87.39
2009	0.57	2.96	4.82	6.02	92.24	98.56	87.69
2010	0.70	8.35	4.52	6.31	91.74	98.89	87.71
2011	0.62	6.64	4.01	5.64	91.33	98.93	87.87
2012	0.68	7.92	3.91	4.98	90.91	98.97	88.03

Table 8
Average of OPE and CPE.

	Biomass	Oil	Coal
Biomass price	−0.44406	0.18066	0.06961
Oil price	−0.30832	0.07679	0.03035
Coal price	−0.0564	−0.19184	0.02082

Table 9
Average of MES.

	Biomass	Oil	Coal
Biomass price		0.62471	0.51367
Oil price	−0.38511		
Coal price	−0.0722		

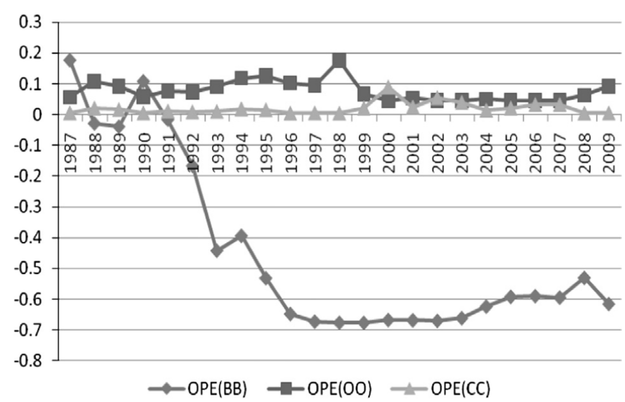

Fig. 11. Changes in the price elasticities of demand for biomass, oil and coal.

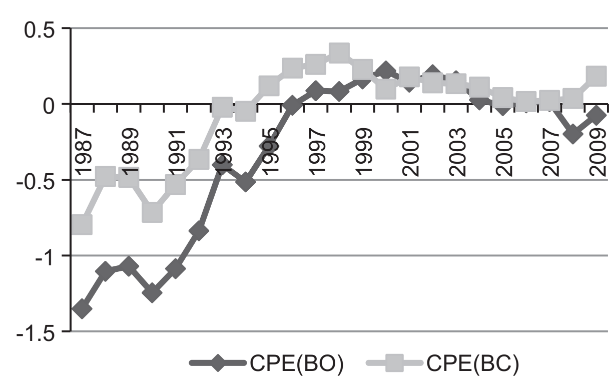

Fig. 12. Price changes of oil and coal affecting the demand for biomass in AES way.

to study the technological substitution between thermal power and biomass power generation. The results shows that thermal power generation and biomass power generation technically play synergistic roles, thermal power technology will help to promote biomass power technology, and from the perspective of current technology level, when the thermal power technology dominates, biomass power technology will not be able to take its place in the near future.

4.1.3. *The empirical results reveal the reason*

First, the natural growth rate of China's current biomass power generation technology is 3.599%, relatively lower than thermal power which is 11.435%. In the absence of any competition or in an unlimited market, the natural growth rate of thermal power is three times as much as biomass power.

Second, China's biomass power generation technology is restricted to various factors of production, economy or market environment, so the space for industry development is relatively limited. Fig. 16 shows China's annual consumption of coal and biomass for the industrial from 1990 to 2009 [11].

Third, competitive coefficients of thermal power and biomass power generation separately are −0.46394 and −3.3655, which are less than zero and reflect the very synergistic relationship. And biomass power generation technology becomes more and more dependent on thermal power technology. Without considering other power generation technologies, the reciprocal relationship does not appear, which indicates that thermal power industry and biomass power industry development are correlated in a mutually beneficial way.

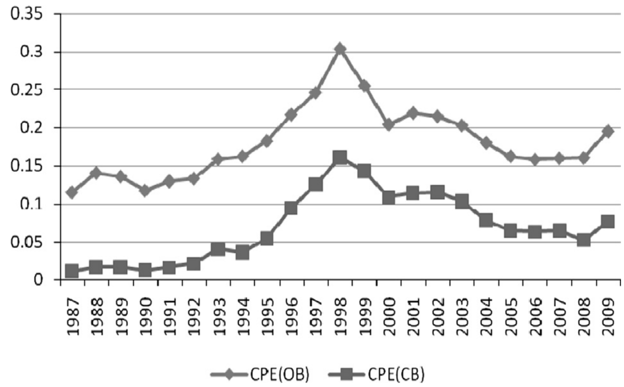

Fig. 13. Price changes of biomass affecting the demand for oil and coal in AES way.

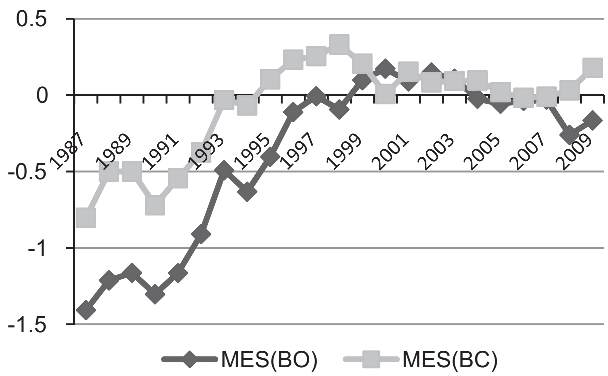

Fig. 14. Price changes of oil and coal affecting the demand for biomass in MES way.

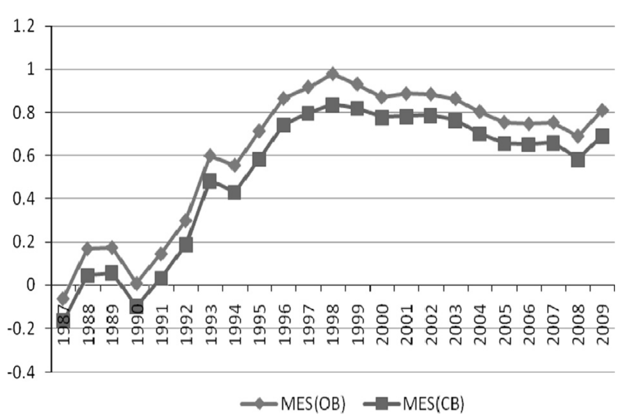

Fig. 15. Price changes of biomass affecting the demand for oil and coal in MES way.

4.2. Costs and efficiency of raw materials for industry development

China′s biomass source material (except straw) prices are far higher than international market prices [36]. Take the grain corn which is the main raw material for ethanol fuel for example, domestic prices are higher than world market ones makes the cost of the domestic ethanol prices higher. According to the analysis of "China′s Fuel Ethanol Industry Research and Prospect—White Paper" from the world′s leading consultancy A.T.KEARNEY, 2007, the cost of China's corn nearly was 80% higher than that of the United States, while correspondingly China's ethanol production cost was 17% higher than that of the United States. At the same time, there was 95.24$ per ton price difference of gasoline prices between China and the United States. What's more, the price of China's fuel ethanol is 18% lower than that of the United States. And that stops China's current ethanol industry from entering the market, so that the producing activities have to rely on government subsidies to guarantee poor profits [10]. Fig. 17 shows the changes in China's food price index.

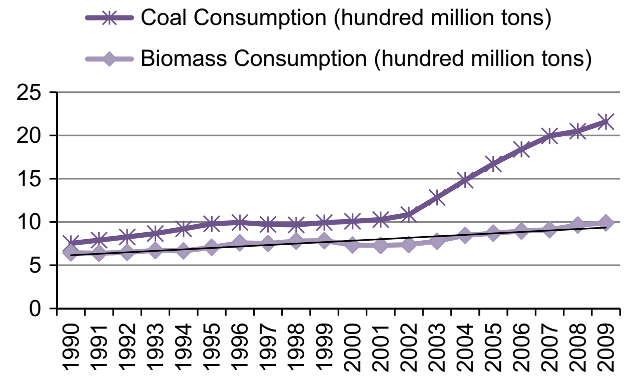

Fig. 16. China's consumptions of coal and biomass for the industrial 1990–2009.

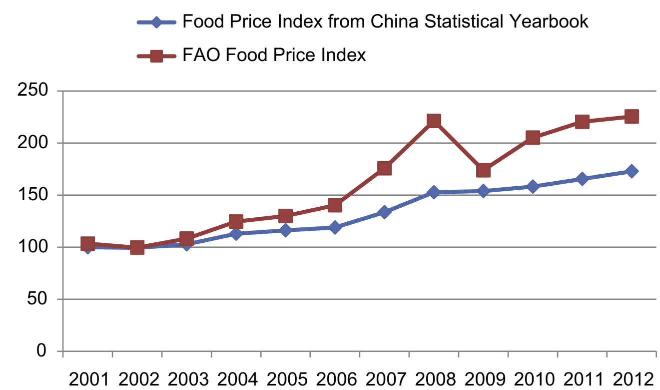

Fig. 17. China Statistical Yearbook's and the FAO's food price index of China (2000 = 100).

Straw and other agricultural and forestry wastes as raw materials for biomass power generation, get neither the centralized channels of the source materials supply, nor the effective regulation formed by market mechanism [24]. The lack of a reasonable guide price makes the development of biomass power industry hard, and the lack of explicit cost prices makes it even harder [26].

In addition, there is a large gap of the production efficiency of fuel ethanol between China and the United States. For example, the number is 12 t of water when producing 1 t of ethanol in China, while the number is 1.8 t in the United States; there needs 3.3 t of corn to produce 1 t of ethanol in China, but the conversion coefficient is 2.8 in U.S.A, hence with more emissions of ethanol production in China than emissions in the United States. From the current perspective, cassava is a commercial material for industrial operation of fuel ethanol [6]. The world's average of producing cassava is 25 t per hectare, which China's mean level with the number of only 20 t per hectare has not reached yet. Ideally, however, level can reach 45 when strengthening field management and fertilizing in time. The cost of cassava ethanol is 285.71–390.48$ per ton lower than the cost of corn ethanol. Assuming the selling prices of cassava ethanol makes 714.29$ per ton, coupled with all kinds of byproducts during producing, the profits of each ton of cassava ethanol will be 169.84$ in the absence of subsidy.

4.3. Current industrial incentive policies and regulations

(1) The enacted related incentives on bioenergy industry before 2009 (Table 10).
(2) The policies and regulations on bioenergy industry from 2009 to 2010 (Table 11).

Table 10
Related incentives for biomass industry 2004–2008.
Source: authors.

Year	Direct incentives	Related favorable policies
2004		NDRC: Clean Development Mechanism Project Development, Reform Operation and Management of Environmental and Resources [2004]
2005		Application Guide for Special Funds from the Government's Environmental Protection Project
2006	"Renewable Energy Law"	National advanced pollution controlling technology demonstration list (the first)
	"Requirements of Managing Renewable Energy Generation"	Identified Management of the Nation Encouraging the Comprehensive Utilization of Resources
	"Pilot Scheme for Managing Renewable Energy Prices and Cost-sharing."	
	"Interim Measures on Renewable Energy Development Special Fund"	
	"Notice of Biomass Power Projects Strengthening Environmental Impact Assessment"	
	"Notice on Strengthening Bio-fuel Ethanol Projects Management, Promoting Healthy Development"	
2007	"Raw Materials Subsidies for Bio-fuels and Bio-chemical"	Order of State Electricity Regulatory Commission [2007] No. 25—Regulatory Approach to Grid Enterprises Purchasing Renewable Energy Electricity
	"Interim Measures to Guide and Reward Bioenergy and bio-chemical for Non-food Raw Materials"	Tax [2002] No. 12—Ministry of Finance State Administration of Taxation Notice on the Improvement of Agricultural Input Tax Deduction Rates
		"Directory of Resources Comprehensive Utilization (revised 2003)"
2008	"Notice of Further Strengthening the Biomass Power Generation Projects and Managing Environmental Impact Assessment"	"State Council Views on Accelerating the Comprehensive Utilization of Crops straw"
	"Interim Measures of Energy Subsidies for Straw Utilization"	

Table 11
Policies and regulations for bioenergy industry development and implementation purposes 2009–2010.
Source: authors.

Year	Policies and regulations	Implementation purposes
2009	"Notice on Planning Guidance to Preparation of Comprehensive Utilization of Straw"	Requiring that based on resource types, current situation and potential development of utilization, direction of development and utilization of straw, planning objectives and key areas of implementation, etc. need to be clear, which relates to the progress required by the planning results
	"PRC's Amendment on Renewable Energy Law"	Implementing renewable energy generation full acquisition system with protection; making clear of the administrative licensing and recording the specific way; integrating the fund of renewable energy development
2010	"Several Policies to Promote the Bio-technology Industry to Accelerate the Development"	Aimed at "China's bioenergy industry into a pillar industry of high-tech fields," a series of policy measures have been proposed, including increasing fiscal policy support, expanding financing channels
	"Policies on Improving Biomass Power Price of the Agriculture and forestry"	Introducing a unified national biomass power generation benchmark electricity price standard for agriculture and forestry: 0.123 $ per kilowatt-hour (tax included)
	"Notice on Managing the Construction of Biomass Power Generation Projects"	Providing that biomass power plants should be arranged in the main area of food-rich areas with straw, and each county or area within a radius of 100 km shall not repeat the layout of biomass power plants

(3) The policies and regulations on bioenergy industry from 2011 to 2013 (Table 12).

5. Obstacles of China's bioenergy industry development

5.1. Market issues

At present, China's bioenergy industry is at a critical stage of development, energy—material market is not mature enough. First, materials are not easy to be collected, so the cost of production is difficult to control and guide for the entire industry [28]; second, Biomass pricing is lack of guidance of market mechanism; what's more, the lacking of sound national standards for the products stops the biomass industry from entering the market [8].

5.2. Raw materials issues

Raw materials issue is currently a global issue for bioenergy development [11,36]. Different from the United States and Brazil, China's bioenergy development is still constrained by the issue of food security. How to deal with the relationship between food security and development of bioenergy in China is a serious problem [5].

5.3. Technical issues

China's bioenergy technical issues, obviously, are rather difficult to be overcome. In China, cellulose fermentation technology is still very immature, and straw direct-fired power generation is less efficient [22]; what's more, ecological protection is a very difficult problem during producing; at the same time, controlling the cost should come along with improving the level of the producing process [31]; eventually, increasing the production of raw materials should rely on technology. Those are 4 aspects that need to be overcome [21].

5.4. Policy issues

Policy issue is the biggest problem for the development of China's bioenergy. First, the bioenergy is in the lack of market accessing system, so the current bioenergy industries are basically monopolized by state-owned enterprises, and various government subsidies cover only these limited number of companies [27]; second, Opportunity Costs of Food and Arable Land problem needs

Table 12
Policies and regulations for bioenergy industry development from 2011 to now.
source: authors.

Year	Policies and regulations	Implementation purposes
2011	"Notice on adjusting and improving the comprehensive utilization of resources and services VAT policy"	The preferential VAT policy is a development funds for comprehensive utilization of straw enterprises (briquette producers)
	"Guidance on further promoting the development of environmental protection industry"	Large urban waste incineration is in need during the Twelfth Five-Year Plan, and the environmental protection industry development will become more important
	"Special plan on waste recycling technology projects during the Twelfth Five-Year Plan"	Major breakthroughs will be key technology and equipment such as the anaerobic digestion of organic waste and the efficient conversion of garbage. The system formation of urban waste should be suited to the utilization of China's energy and resource
	"State Council approving the Housing and Urban Construction Department and other departments on further strengthening the disposal work of urban living garbage"	We should promote waste product recycling, incineration, treatment and other utilizations of garbage resource. It's necessary to accelerate the recycling of biomass energy, improve solid waste incineration power generation and efficiency of landfill gas power generation
	"Interim Measures of Fund imposition for Renewable Energy Development"	Tariff surcharge of renewable energy is at the standard of 0.001312%/kW h
	"Interim Measures of subsidies for Green energy demonstration counties"	The methane gas projects: For the projects with annual output of 100,000 m^3 above, Grant funds is to support the facilities of biogas purification treatment, gas tank, construction of transmission pipeline; The biomass gasification projects: For the projects which can supply gas for 200 or more residents, Grant funds focus on supporting facilities of gas cleaning purification treatment, gas tank and construction of transmission pipeline; The biomass briquette projects: For the projects with annual production capacity of 5000 t and more, Grant funds is to support the purchase of biomass cooking stove, instruments and transformation
2012	"National Development and Reform Commission's notice on price policy of improving waste incineration power"	The higher part of waste incineration power tariff than the local desulfurized coal tariff will be under the implementation of two-level distribution. Among them, the local provincial grid should be responsible for 0.0164 $ per kW h, while the increasing the cost of purchasing electricity for power companies should be compensated by the sales price of electricity; the rest will be solved by the national levied additional tariff of renewable energy. And we will strengthen the price regulation of waste incineration power
	"Biomass energy development plan during the Twelfth Five-Year Plan"	By 2015, we should establish a relatively complete industrial system of biomass power, and achieve the initial realization of commercialization and scale in electricity, heating, energy use of rural areas
2013	"National Forestry Biomass Energy Development Plan (2011–2020)"	By 2015, we will build 8.38 million hectares of fuel forest, wood energy forest and starch energy forest, which makes the forestry biomass consumption be over 10 Mtce. Among them, the contribution rate of liquid biofuel is 10%, and the contribution rate of biomass thermal utilization is 90%. By 2020, we will build 16.78 million hectares of energy forest, which makes the forestry biomass consumption be over 20 Mtce. Among them, the contribution rate of liquid biofuel is 30%, and the contribution rate of biomass thermal utilization is 70%

to be solved to achieve agricultural–industrial development hand in hand; third, subsidies lack of scientific theory and method as a guide, so the incentive effect is not ideally obvious [5,30]; at last, industry development policy framework is not perfect enough that the development is short of powerful support [26].

6. Conclusions and policy recommendations

6.1. In summary, here are the conclusions

- The bioenergy industry is an effective way to help to achieve China's energy security. This requires China to optimize energy consumption structure, reduce reliance on primary energy while strengthen development and utilization of renewable energy, so as to enhance energy self-sufficiency and ensure rapid economic development of local energy supply security.
- In the support of achieving energy security, bioenergy industry should keep up with the pace of new orientation of China and the world. It is wise to develop domestic renewable energy as reserve energy.
- As for energy substitution from cost aspect, China has already had the ability to make bioenergy substitute for fossil fuels. Prices of both stale rice and non-food materials are actually lower than the international mean level. Using domestic materials at a low price is suitable for China to develop bioenergy industry. In a sense, enterprises should take advantage of the current situations of the costs.
- From technical aspect, however, China's bioenergy technologies are not mature, this means that in a very long period of time, biomass and fossil energy will jointly develop in a mutually beneficial way. International cooperating projects may be a useful way to solve this problem.

6.2. Policy recommendation

China urgently needs a scientific and reasonable mechanism and policy framework for bioenergy industry development. By using market price and subsidy incentives to meet the need of sustainable development for bioenergy industry, energy security and food security will achieve ultimately.

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